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FAIR implementation choices for ITINERIS HUB: Design document

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LIST OF ACRONYMS

CC BY 4.0: Creative Commons Attribution 4.0 International License

CERIF: Common European Research Information Format

DCAT-AP: Data Catalog Vocabulary Application Profile

DO: Digital object

ENVRI-FAIR: ENVironmental Research Infrastructures building Fair services Accessible for society, Innovation and Research

EOSC: European Open Science Cloud

EPOS: European Plate Observing System

FIP: FAIR Implementation Profile

FER: FAIR Enabling Resource

FIC: FAIR Implementation Community

JSON-LD: JavaScript Object Notation for Linking Data

NOAA: National Oceanic and Atmospheric Administration

NetCDF: Network Common Data Form

RI: Research Infrastructure

1. SUMMARY

The present document represents a preliminary version of the planned FAIR implementation choices for the ITINERIS HUB and the overall suite of Digital Objects (DOs) it will contain. The FAIR experts from WP2, in collaboration with the HUB developers, have carried out an initial selection of key FAIR enabling resources (FERs) that will be adopted. This selection has been formalised into a specific FAIR Implementation Profile (FIP) that is currently not exhaustive and will undergo further refinement and improvement. However, to provide an initial contextual analysis of the choices made regarding FAIR practices with respect to other research infrastructures (RIs) involved in ITINERIS, a convergence analysis of the FERs currently available at the European level has been conducted. This work provides the basis for the selection and adoption of appropriate FAIR practices for the various DOs that will be available on the ITINERIS HUB, through a consolidated technological/methodological approach actionable by both human and machine entities.

1. INTRODUCTION

The FAIR principles constitute one of the best collective efforts made in recent years to promote the openness and appropriate sharing of research data (Wilkinson et al., 2016) and other research outputs (e.g.: semantic resources, software, workflows, etc.). In this context, the European Union has prioritised the transition of the scientific system towards open science (EU Commission, 2015). To support this transition, Burgelman et al. (2019) suggest the adoption of technical solutions based on FAIR principles and emphasise leveraging them in a federated infrastructure (e.g., EOSC - European Open Science Cloud) to enhance data accessibility and interoperability. The European Open Science agenda contains the ambition to make FAIR data sharing the default for scientific research by 2020 (Burgelman et al., 2019). Promoting FAIR data sharing as a widespread practice in funding scientific research is essential. This will enable all European researchers to easily deposit, access, and analyze European scientific data through the EOSC. In addition, Bailo et al. (2023) stress the importance of integrating FAIRness objectives into Research Infrastructures (RIs), especially those operating internationally.

Since their publication in the scientific field, the FAIR principles have served as a breakthrough in open data management and to make DOs from different sources available to society (Peters-Von Gehlen et al., 2022). However, FAIR principles are aspirational in the sense that they do not strictly define how to achieve the ideal state of FAIRness, but rather describe a series of instructions, attributes, and behaviours that researchers can follow to reach this goal (Wilkinson et al., 2019).

With regard to the adaptation of the FAIR principles to the concrete realities and specific needs of multidisciplinary RIs that provide integrated access to (meta)data from different sources, several projects and HUBs can be mentioned. At the international level, the National Oceanic and Atmospheric Administration (NOAA) data portal[1] represents an outstanding reference for free access and sharing of environmental data and services in a FAIR way[2]. Similarly, The European Open Science Cloud (EOSC)[3] is a key pan-European project that provides a common catalogue for European researchers for discovering and accessing research data, services and software for research.

[1] https://www.ncei.noaa.gov

[2] https://sab.noaa.gov/wp-content/uploads/NOAA-Response_SAB_Report_Open_Data_Open-Science-1.pdf

[3] https://eosc-portal.eu

Finally, at national level, Data Terra[4] is the French research e-infrastructure focused on the Earth system and environment, whereas the Nationale Forschungsdaten Infrastruktur (NFDI) represents national research data infrastructure for Germany[5].
Similar to the previously described infrastructures, the ITINERIS HUB will provide a single contact point to discover, access, use, and reuse a wide range of environmental research resources and services of the Italian RIs, following the FAIR principles and the Open science practices. The goal of creating an HUB like the one described here is certainly ambitious and poses significant challenges. The ITINERIS contact point will need to aggregate DOs from different RIs not only across different domains but also at various levels of FAIRness maturity. It will therefore be crucial to employ FAIR strategies capable of adapting to these diversities and ensure that their implementation follows a clear and straightforward approach. The ENVRI-FAIR project is certainly an excellent reference to follow, having tackled similar challenges and consequently proposing standardised and machine-readable approaches.

2. SCOPE

Taking into account the guidelines emerging from ENVRI-FAIR (see for example Peterseil et al., 2023), this deliverable aims to represent an initial design plan of the ITINERIS HUB and the different DOs that will be exposed on it, through the use of FAIR Implementation Profiles (FIP) as a formal tool for describing the FAIR technological choices and their implementation strategy.

However, since the ITINERIS project integrates nationally funded RIs, European ESFRI, and non-ESFRI RIs, which may have distributed national nodes with different levels of autonomy and a wide range of FAIR readiness (see deliverable 2.7), the selection of appropriate FAIR choices is not a simple task and requires a specific design plan. For this reason we decided to adopt a common strategy, in order to achieve a comprehensive release of the ITINERIS FIPs prior to the project's conclusion, and which can be outlined as follow:

1. A first release of the ITINERIS FIP containing a detailed description of the FAIR implementation choices for the Data Hub (mainly time series data for the first release of this deliverable);
2. A convergence analysis between the first release of ITINERIS FIP (Data Hub) and the existing FIPs available by the FIP Wizard for the RIs that are relevant for the ITINERIS project;
3. An implementation plan for the final ITINERIS FIPs, including a new convergence analysis with the available FIPs that will be produced by the national nodes of RIs and domain repositories of ITINERIS.

This document primarily focuses on the first and second points, providing detailed information and analysis. However, the third point will not be addressed here. Instead, it will be discussed in a separate document at a later stage.

[4] https://www.data-terra.org/en/
[5] https://www.nfdi.de

3. METHODS

3.1. FAIR Implementation Profile (FIP)

A FIP is essentially a compilation of declarations, representing technology choices known as FAIR Enabling Resources (FERs), made by a specific community of practice, termed the FAIR Implementation Community (FIC), to adhere to one or more FAIR Guiding Principles (Schultes et al. 2020; WiKi[6]). These declarations, captured as nanopublications, serve as a tool to track the progress of different FAIR DOs used by selected RIs. Moreover, FIPs can provide information about the level of convergence among RIs by assessing the common FERs shared between them. Comprising 21 questions, a FIP is compiled by a designated individual responsible for (meta)data management within a particular FIC, utilising the FIP Wizard[7]. Answering a question with an existing resource identifies it as a FER, indicating fulfilment of a specific FAIR sub-principle. The FERs can be designated as either "available" for reuse or "in development". For each of the FAIR principles there are defined types of FERs as described in Table 1.

Table 1. Types of FAIR Enabling Resources (FERs) and their connection with individual FAIR principles. The table is adapted from Peterseil et al. (2023).

DEFINED TYPES FOR FAIR ENABLING RESOURCES

FAIR principles		Type of FAIR Enabling Resource	Brief description
FINDABILITY	F1	IDENTIFIER SERVICES	A service that provides for any digital object (1) algorithms guaranteeing global uniqueness, (2) policy document that guarantees persistent and (3) resolution of the identifier to machine-actionable metadata describing the object and its location.
	F2	METADATA SCHEMA	A specification that defines metadata fields describing attributes of data or other digital objects.
	F3	METADATA-DATA LINKING SCHEMA	A specification that provides a unique, persistent, (ideally) bi-directional, machine-actionable link between metadata and the data they describe.
	F4	REGISTRY	A service that indexes metadata and data and provides search over that index.
ACCESSIBILITY	A1.1	COMMUNICATION PROTOCOL	A specification that defines how messages are structured and exchanged.
	A1.2	AUTHENTICATION & AUTHORISATION SERVICE	A service that mediates access to digital objects according to specified conditions.
	A2	METADATA PRESERVATION POLICY	A document that describes the conditions under which metadata are to be provisioned in the future (maybe part of a data management plan).
INTEROPERABILITY	I1	KNOWLEDGE REPRESENTATION LANGUAGE	A language specification that enables knowledge to be processed by machines.
	I2	SEMANTIC ARTEFACTS	A specification of uniquely identified and unambigous concepts with their definitions represented preferably using web standards.
	I3	SEMANTIC MODEL	A specification that defines qualified relations between entities describing data or other digital objects according to the Linked Data principles. This can include semantic data models and ontologies.
REUSABILITY	R1.1	USAGE LICENSE	A document that describes the conditions under which a digital object can be legally used
	R1.2	PROVENANCE MODEL	A specification that defines metadata fields describing the origin and lineage of data or other digital objects.
	R1.3	FIP AS A WHOLE	R1.3 is not specifically requested as the whole FIP is interpreted as community specific metadata.

FIPs are not a goal in and of themselves. The primary purpose of creating and maintaining FIPs is to accelerate the wide-spread adoption of FAIR-enabling standards through a shared and formal tool that can track the various stages of FAIR implementation.

[6] https://gofair-foundation.gitHUB.io/fip/MintingNanopublications.html
[7] https://fip-wizard.ds-wizard.org/

3.2. FAIR convergence assessment

The methodological approach of the FAIR convergence assessment is based on the overlap and convergence of FERs used by the different RIs. As already described by Peterseil et al. (2023), convergence can be defined as "... a phase of infrastructure development *when a broad stakeholder community chooses to deploy the same enabling technologies* ...". This can be described by the use of shared FERs which are defined as "*FER that is commonly used and implemented by at least two RIs and their repositories*". Following these concepts, FAIR convergence would then be seen as a valuable approach to explore the sharing of common FAIR implementation choices across RIs and the potential interconnection of their catalogues, data, metadata, and services with the ITINERIS HUB.

Results from selected RIs FIP surveys were used to explore the ITINERIS FAIR implementation choices convergence. Specifically, we considered as a convergence indicator the absolute number of bilaterally shared FERs with the ITINERIS FIP. Based on this kind of proximity/similarity assessment, results were then visualised as heatmaps and a network graph.

Regarding the existing FIPs selection process, it must be considered that, at the moment, no FIPs of the national nodes of the RIs involved in the ITINERIS project are available. Only LifeWatch Italy has produced a first release of its FIP (see deliverable D2.8). Therefore, we selected the most recent FIPs available at European level for the RIs that are part of ITINERIS. Specifically, we downloaded all the FIPs from the nanopublication API query[8] that assembles the results as a .csv file from a sequence of SPARQL queries. This customised query allows the direct download of all the available FIPs that are published through the FIP Wizard[3]. The table was subsequently processed by selecting only the RIs participating in ITINERIS plus the available SeaDataNet FIPs (i.e. SeaDataNet-CDI and SeaDataNet-Sextant) and EPOS ERIC. SeaDataNet has been analysed along the ITINERIS RIs because the marine subdomain RIs (e.i., JERICO and EuroFleets) make use of such infrastructure. Moreover, we considered EPOS ERIC in order to collect information also for the geosphere-landsurface subdomain for which any of the RIs involved in ITINERIS have a FIP. We took into consideration the most updated version of each FIP (last visit 15.02.2024). Only the FERs that were declared as "available" and "in use" by each community have been selected.

4. FAIR IMPLEMENTATION CHOICES FOR ITINERIS HUB

The ITINERIS FIP for Data Hub was collaboratively compiled during an online session by the WP2 representative for the FAIR Implementation Working Group and the developer team that are familiar with FIP Wizard, having created the ACTRIS FIP in the framework of ENVRI-FAIR project. Moreover, the GO FAIR Foundation recommends facilitator assistance for FIP compilation and the WP2 representative received training on this.

The FAIR implementation choices reported into ITINERIS FIP was substantially reported for the time-series data that will be exposed into the Data Hub. At present, there are 21 unique declared FERs "planned to use" out of a total of 38 FER declarations. In particular, we can summarize the FAIR choices as follow:

[8] https://gitHUB.com/peta-pico/dsw-nanopub-api/blob/main/tables/new_matrix.csv

- the Digital Object Identifiers (DOI) will be the unique, persistent, resolvable identifier to make DOs easily discoverable and referenceable;
- the Data Catalog Vocabulary Application Profile for Data Portals in Europe (DCAT-AP) will be adopted as metadata schema together with CERIF and ISO 19139;
- the Catalog Service for the Web (CSW), GeoNetwork API, GeoServer REST API, Open Geospatial Consortium Catalogue Services 3.0 (OGC CS), Web Coverage Service (WCS), Web Feature Service (WFS), Web Map Service (WMS) will be the standardized communication protocol to access the DOs;
- JSON-LD and NetCDF have been chosen as knowledge representation languages for metadata and data, respectively;
- CC BY 4.0 is the license that will be used for both data and metadata;
- no authentication and authorisation service for the access to the various DOs are planned.

All the FAIR implementation choices for the ITINERIS Data Hub are reported in detail into the specific ITINERIS FIP that is publicly accessible under a CC-BY licence, in both human and machine-readable formats[9]. In all the following figures and tables, the label ITINERIS expressly refers to the ITINERIS FIP for Data Hub.

5. FER CONVERGENCE LEVELS

For the convergence analysis with the ITINERIS Data Hub FAIR implementation choices, a total of 20 FIPs have been selected including RIs or single components of it related to FICs. As result, the final FIPs selected for each community are: six FIPs from the different ACTRIS ERIC units (Cloud remote sensing data centre unit "ACTRIS_CLU", Data discovery-virtual access and Services unit "ACTRIS_DVAS", Trace gases remote sensing data centre unit "ACTRIS_GRES", In-Situ data centre unit "ACTRIS_InSitu", Aerosol remote sensing data centre unit "ACTRIS-ARES", Atmospheric simulation chamber data unit "ACTRIS-ASC"), the FIPs form DANUBIUS, ICOS, SIOS, Euro-Argo ERIC Global Data Centres "ArgoGdac", EMSO, the Common Data Index service of SeaDataNet "SeaDataNet-CDI", the product catalogue service and system for SeaDataNet "SeaDataNet-Sextant", Anaee, AnaEE_CREA (the centre responsible for the Data & Modeling Centre), eLTER-RI, LWERIC_Ecosystem (which correspond to the digital services offered by the LifeWatch ERIC Service Centre), and lw-marine (which correspond to the digital services offered by the Belgian node). The communities represent in total nine ITINERIS RIs (ACTRIS ERIC, AnaEE ERIC, EMSO ERIC, Euro-Argo ERIC, ICOS ERIC, LifeWatch ERIC, DiSSCo, eLTER and SIOS) plus SeaDataNet and EPOS ERIC.

The selected FIPs were then aggregated into the different environmental RIs considered in ITINERIS and into the four subdomains as described in the Table 2. This grouping consists in a simple aggregation of the different raw binary matrices (presence of a given FER) without any further weighting. Finally, it is important to note that ICOS and SIOS, due to their multidisciplinary nature, were assigned to more than one subdomain but released only one FIP, so the information was counted in each subdomain (see Table 2).

Table 2 - List of the FIPs considered and their aggregation into the selected European RIs and subdomains for the comparison analysis with the ITINERIS FIP. Note that ICOS and SIOS were

[9] https://fip-wizard.ds-wizard.org/wizard/projects/60967fec-59ae-46d8-9de7-a6df131bf122

placed in more than one subdomain, due to their multidisciplinarity nature, but developed only one FIP.

Subdomain	RI	FIP Name
ATM	ACTRIS ERIC	ACTRIS_ARES
		ACTRIS_ASC
		ACTRIS_CLU
		ACTRIS_DVAS
		ACTRIS_GRES
		ACTRIS_InSitu
	ICOS ERIC	ICOS_ERIC
	SIOS	sios
MAR	EUROArgo ERIC	ArgoGdac
	EMSO ERIC	EMSO
	ICOS ERIC	ICOS
	SIOS	sios
	DANUBIUS	DANUBIUS
	SeaDataNet	SeaDataNet-CDI
		SeaDataNet-Sextant
GEO	EPOS ERIC	EPOS-ERIC
BIO	Anaee	Anaee
		AnaEE_CREA
	eLTER	eLTER-RI
	ICOS ERIC	ICOS
	LifeWatch ERIC	lw-marine
		LWERIC_Ecosystem
	SIOS	sios

Considering the total number of shared FERs, the convergence between ITINERIS and other European RIs was not particularly high (Fig. 1). In particular, the analysis revealed 11 FERs shared with SeaDataNet and ICOS ERIC, whereas a low level of overlap with EPOS was reported, sharing only 5 FERs. Considering all the other European RIs, the FAIR convergence level was equal or lower than 8. For comparison, the ACTRIS ERIC was the RI with the highest number of shared FERs, ranging from 29 (with ICOS ERIC) to 8 (with ITINERIS and EMSO ERIC).

For ITINERIS, the FAIR convergence level was mainly reached for the Findability principle (Fig. 2A) and with highest number of shared FERs with ICOS ERIC (5 FERs), ACTRIS ERIC, Anaee, LifeWatch ERIC, and eLTER (3 FERs). DOI was the most common FAIR implementation choice adopted by Findability, as it was selected by ITINERIS Data Hub and all European RIs considered, with the exception of EMSO ERIC. Moreover, DCAT-AP resulted as the most common choice among the metadata schemas, as it was adopted by ITINERIS Data Hub and four different RIs (ICOS ERIC, LifeWatch ERIC, Anaee, EPOS ERIC).

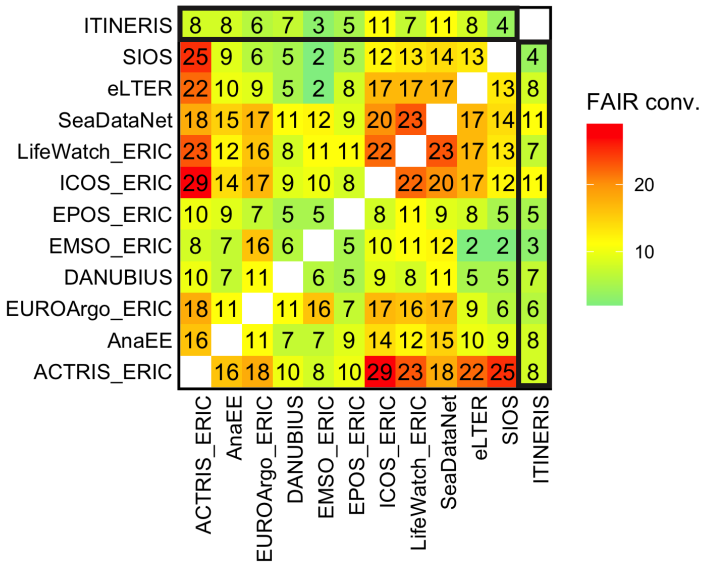

Figure 1 - FAIR convergence heatmap between ITINERIS Data Hub and the selected European RIs showing the total number of bilaterally shared FERs.

Conversely, the ITINERIS Data Hub FERs for Accessibility and Interoperability emerged to have a general low FAIR convergence level in relation to the other RIs (Fig. 2B and 2C). However, the few declared communication protocols (OGC CSW, WMS, WFS, WCS web services) and data formats (NetCDF) were widely adopted by the other European RIs.

FERs declared for Reusability emerged with a good convergence level. This was mainly related to the choice of the CC BY 4.0 license for data and metadata, which is a FAIR implementation shared among all RIs considered in our analysis and ITINERIS Data Hub

Finally, examining the number of ITINERIS FERs in common with the different subdomains, we can say that the planned FAIR choices resulted quite similar to that of the marine, terrestrial, and biosphere subdomains (sharing 12, 18, and 16 FERS, respectively), but with a very low FAIR convergence level respect to geosphere subdomain.

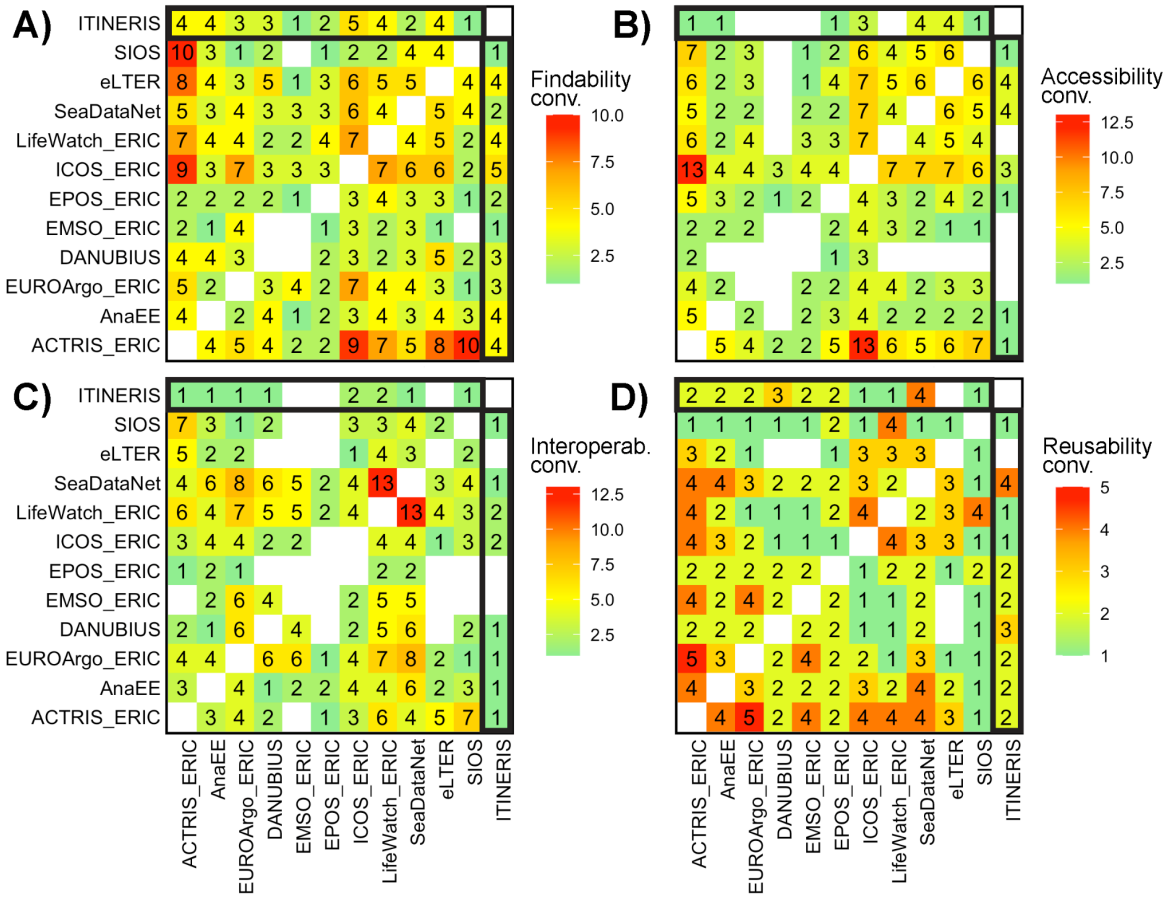

Figure 2 - FAIR convergence heatmap between ITINERIS and the selected European RIs showing the total number of bilaterally shared FERs for A) Findability, B) Accessibility, C) Interoperability, and D) Reusability principle.

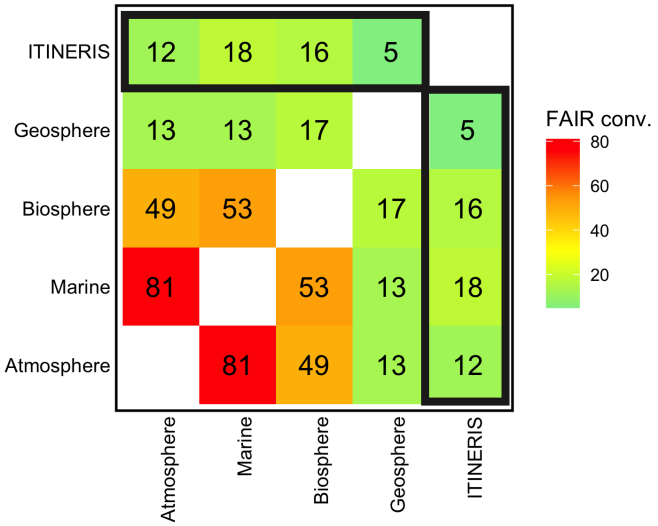

Figure 3 - FAIR convergence heatmap between ITINERIS and the selected European RIs grouped by subdomains showing the total number of bilaterally shared FERs.

6. CONCLUDING REMARKS AND FUTURE WORK

In this deliverable we provided an initial brief description of the FAIR implementation choices planned for the ITINERIS Data Hub, formalising these choices within a dedicated FIP. However, the document is only a preliminary version because the Data Hub, as the other components of ITINERIS HUB, are still in the designing and/or implementing phase. The responses of the ITINERIS Data Hub FIP were mainly given for "time series data". All other DOs (services, codes, software, VREs, documents, trainings etc.) that will be exposed in the catalogue or other components of ITINERIS HUB were not considered in this document. A second release of this document is planned in the next months, where the FIPs for all the components of ITINERIS HUB will be provided.

It is necessary to specify that, for the same reasons (designing and/or implementing phase), the Terminology Service and semantic artefacts which will be provided as products of the project, have not been taken into consideration into the FIP. For this reason the FERs for interoperability of Data Hub resulted in a low convergence level with the RIs.

Furthermore, all FAIR implementation choices have been defined in the FIP as "planned to use," given that we are at the beginning of the implementation phase. In a future release of this document, it will be possible to evaluate which choices have been effectively adopted and implemented.

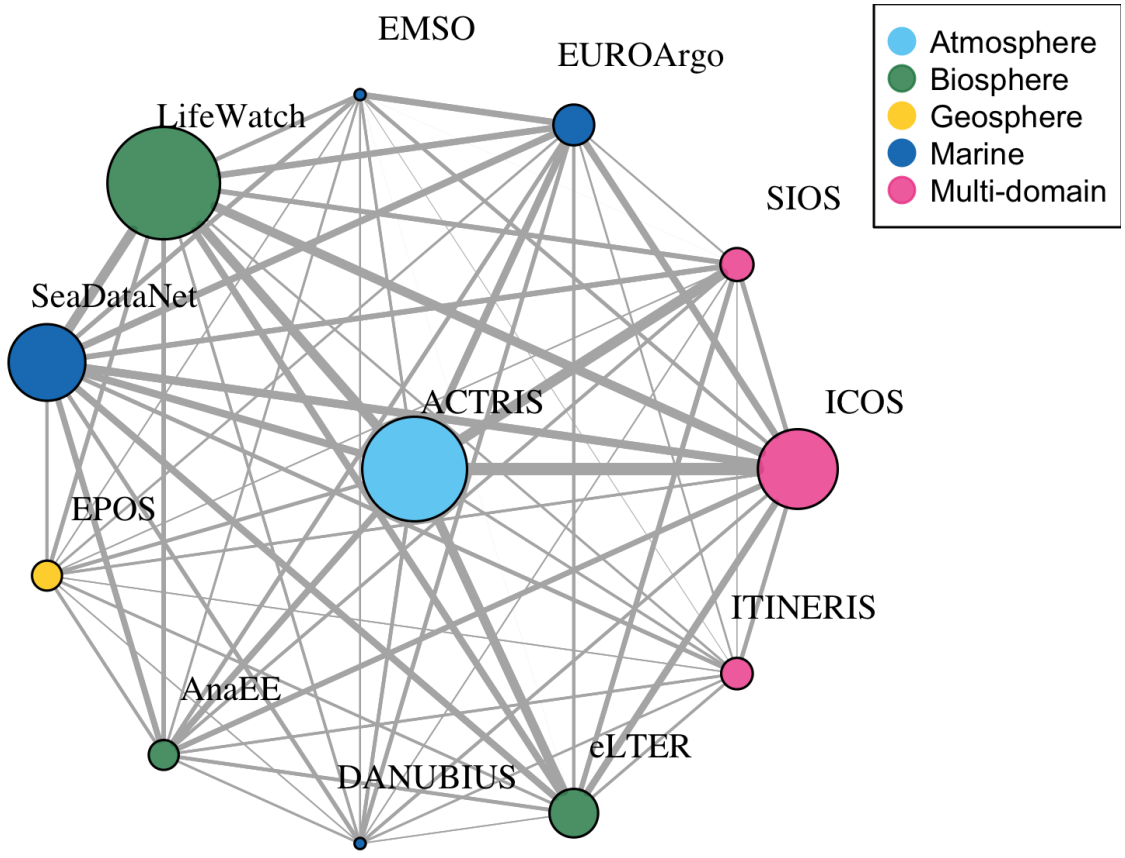

Figure 4 - Network graph about convergence level between FAIR implementation choices adopted by ITINERIS Data Hub and the different European RIs. The size of the nodes is proportional to the total number of declared FERs, while the thickness of the connections is proportional to the number of FERs shared between two nodes (i.e., RIs).

Regarding the FAIR convergence analyses presented in this deliverable, the ITINERIS resulted to have a relevant number of FERs in common with the selected European RIs. Representing these results into a network graph (Fig. 4), it is interesting to note how currently the ITINERIS choices for Data Hub occupy a marginal position in the network, with a good number of connections but all with low intensity. Instead, ACTRIS plays a central role within the network thanks to the numerous and strong connections with all the other European RIs. The next work of the WP2 will be to allow ITINERIS to have a central position within this network, by improving the number of FERs and their level of sharing among the national nodes of the involved RIs.

This kind of analysis represents a useful tool for evaluating the extent to which FAIR implementation choices are shared among RIs and their "potential connectivity" level. However, it is worth mentioning that this connectivity analysis is obviously proportional to the number of FERs adopted by each RI or the different subdomains. In fact, greater is the number of FERs declared by a RI (or subdomain), more probably they are in common/shared by the other RIs (or subdomain). In particular, in the case of Geosphere subdomain (Fig. 3), since it is represented only with a singular FIP developed by EPOS ERIC, it has the lowest number of declared FERs and, consequently, this resulted in the lowest convergence level with respect to the other subdomains.

Finally, it's important to note that a low number of bilateral shared FER does not exclude the possibility that a particular choice has a high level of FAIRness. For example, the DCAT-AP adopted by EPOS and ITINERIS is an excellent choice for mapping and harvesting metadata from various distributed sources, even though this metadata schema is currently not widely shared among all RIs. So, it is always necessary to have a detailed description of the different FER choices to properly assess the general FAIR level and possible implementation actions.

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